EFFECT OF L-CARNITINE ON STARTER PIG PERFORMANCE AND FAT UTILIZATION

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Summary

Three hundred early-weaned pigs with average initial weights of 12.3 and 13.2 lb, respectively, were utilized in two 5-wk experiments to determine the effect of L-carnitine on growth performance. Diets contained 20% dried skim and 20% dried whey in phase 1 (0 to 14 d) for both experiments and 20 and 10% dried whey, respectively for experiments 1 and 2 in phase 2 (15 to 35 d). In experiment 1, L-carnitine at levels of 0, 500, and 1000 ppm was combined with 0 or 10% soybean oil in phase 1, levels were reduced by 50% in phase 2 to 0, 250, and 500 ppm L-carnitine and 0 or 5% soybean oil. There was no improvement in pig performance from addition of either L-carnitine or soybean oil in phase 1. In phase 2 and for the cumulative 5 wk experiment, soybean oil addition improved average daily gain (ADG) but had no effect on feed intake (FI) or feed/gain (F/G). Feed efficiency was improved linearly as the level of L-carnitine was increased in phase 2, however, there was no effect on ADG or FI. In experiment 2, L-carnitine levels in phase 1 were 0 and 1000 ppm, combined with levels of 0, 250, and 500 ppm in phase 2. Addition of L-carnitine improved ADG and increased FI, but had no effect on F/G the first 2 wk postweaning. In phase 2, increasing the level of L-carnitine resulted in improved F/G. Feed intake was decreased as L-carnitine level increased. There was no effect on ADG in phase 2 or during the cumulative 5 wk experiment from level of L-carnitine fed. Feed efficiency improved and FI decreased over the 5 wk trial as the level of L-carnitine increased. Based on the results of these experiments, addition of L-carnitine shows the potential to improve F/G by 11 to 16% in phase 2 and 7 to 9 % for the overall starter phase.

(Key Words: Starter, Performance, Carnitine, Soybean Oil.)

Introduction

The common practice of weaning pigs at 3 weeks of age or less has increased the problems with postweaning lag in many swine operations. Early weaning results in many lightweight pigs (< 11 lb), which require highly palatable and highly digestible diets. A high nutrient density diet (high in fat and milk products) has been researched vigorously in recent years at Kansas State University and developed as a specialty diet for the early-weaned pig. Typical high nutrient density diets contain 40% milk products and 10% added fat (soybean oil or choice white grease). Recent research has shown early-weaned pigs to have difficulty in utilizing the fat in these diets. This is somewhat surprising because the pig does quite well on sow's milk, which is 35% fat on a dry matter basis. However, one nutrient quite high in sows

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milk is carnitine, which is normally quite low in the diets fed early-weaned pigs. Therefore, the present studies were designed to determine the effect of L-carnitine on performance and fat utilization of the early weaned pig.

Procedures

Experiment 1. A total of 120 crossbred pigs was weaned at 19 ± 2 d with an average wt of 12.3 lb and utilized in a 5-wk growth trial. Pigs were housed in an environmentally controlled nursery in 4 × 5 ft pens. Feed and water were supplied ad libitum, and pig and feed weights were recorded weekly. Pigs were allotted to one of the six dietary treatments by litter, sex, and weight. Five replications per treatment with four pigs per pen were used. The experimental treatments were in a 2 × 3 factorial arrangement with two levels of soybean oil (0 or 10%) combined with three levels of L-carnitine (0, 500, or 1000 ppm) in phase 1 (0 to 14 d). In phase 2 (15 to 35 d), additions were cut in half resulting in soybean oil levels of 0 and 5% combined with L-carnitine levels of 0, 250, and 500 ppm. Phase 1 diets were formulated to contain at least 1.3% lysine with a constant calorie/lysine ratio of 250 kcal ME/g lysine. Compositions of experiment 1 diets are shown in Table 1. All diets were pelleted.

Experiment 2. A total of 180 pigs was weaned at 22 ± 2 d with an average initial wt of 13.2 lb and utilized in a 5-wk growth trial. Facilities, method of allotting pigs, method of diet preparation, and methods of feeding were identical to those in experiment 1. The soybean oil level was decreased to 5% for the entire 5 wk experiment, because no response to soybean oil addition was shown in phase 1 of exp. 1. A 2 × 3 factorial arrangement was used again with two levels of L-carnitine (0 or 1000 ppm) in phase 1 combined with three levels (0, 250, or 500 ppm) of L-carnitine in phase 2. Phase 1 diets were formulated to contain 1.45% lysine and phase 2 diets 1.25% lysine. Compositions of experiment 2 diets are shown in Table 2.

Results and Discussion

Experiment 1. Growth performance data are reported as interaction means in Table 3. Because there was no L-carnitine × soybean oil interaction ($P>.12$), main effects for L-carnitine and soybean oil will be discussed. There was a numerical trend for higher ADG and improved F/G for pigs fed the high levels of L-carnitine in combination with soybean oil. Pig performance in phase 1 was similar among all treatments, with no response to addition of either L-carnitine or 10% soybean oil (Table 3). However, in phase 2, feed efficiency was improved linearly ($P<.05$) as the level of L-carnitine was increased. There was no L-carnitine effect on pig performance for the cumulative 5 wk experiment. Addition of soybean oil improved ($P<.05$) ADG in phase 2 and for the cumulative 5 wk trial.

Initially, most of the response to L-carnitine would have been expected to be in phase 1, because this is when carnitine synthesis by newly weaned pigs is lowest. The high nutrient density diets fed were analyzed to contain 100 ppm L-carnitine without additional supplementation. This is considerably higher than diets without milk products and may partially explain why the response to L-carnitine was somewhat variable in phase 1. In phase 1 there was a numerical trend for 1000 ppm L-carnitine to decrease FI and ADG in combination with no soybean oil, whereas addition of 500 ppm L-carnitine gave an improved response in ADG and FI. This suggests that the carnitine requirement was met at the intermediate level and that the requirement was exceeded with the higher level, resulting in lowered performance. For pigs receiving diets with soybean oil added, the highest ADG and feed efficiency levels were achieved at the highest level of L-carnitine supplementation, suggesting that pigs fed fat may have higher carnitine requirements than those no fed fat.

Feeding of fat in phase 1 gave no improvements in pig performance; however, before fat is totally eliminated from the phase 1 diet, several other factors need to be considered. High milk product diets need to contain at least 3% fat to be pelleted and have acceptable pellet quality and mill throughput. Secondly, previous research has shown that pigs require an adjustment period to utilize fat. Consequently, improved performance from fat addition in phase 2 requires at least some fat to be fed in phase 1.

Experiment 2. Main effects of L-carnitine addition on growth performance in phase 1 are shown in Table 4. Pigs fed 1000 ppm L-carnitine had higher ($P<.02$) feed intakes and improved ($P<.08$) ADG in phase 1. Dietary treatment fed in phase 1 had no effect on pig performance in phase 2 nor for the cumulative 5 wk of the experiment.

Pig performance data are reported as interaction means for the combination of L-carnitine level fed in phase 1 and phase 2 and are shown in Table 5. Phase 1 growth data can be compared only as the main effect of L-carnitine level fed in phase 1, because carnitine level fed in phase 2 could not affect performance of pigs in phase 1. Contrary to the increased FI response of L-carnitine addition in phase 1, FI decreased linearly ($P<.05$) as the level of L-carnitine was increased in both phase 2 and for the cumulative 5 wk trial. Feed efficiency was improved linearly ($P<.03$) and quadratically ($P<.02$) as levels of L-carnitine were increased in phase 2. A similar linear improvement ($P<.06$) in F/G with increasing level of carnitine was also found over the cumulative 5 wk trial.

In this experiment with fat added to all diets, addition of 1000 ppm L-carnitine improved FI and ADG in phase 1, suggesting that we were correct in our thoughts that pigs fed fat-added diets have higher carnitine requirements than those not fed fat. This improved performance in phase 1 did not carry through to phase 2, which may be explained partly by the fact that very little postweaning lag was observed in either experiment. The improved FI from L-carnitine addition may prove to be more beneficial in operations where pigs don't eat well immediately following weaning and postweaning lag is a major problem.

In phase 2, in agreement with experiment 1, L-carnitine addition again improved feed efficiency; however there was an equal improvement regardless of whether the pigs received L-carnitine in phase 1 or not. Carnitine has several roles in nutrient metabolism in pigs. Our experiments indicate that tissue synthesis of carnitine may not be sufficient to optimize pig performance.

Based on the results from these two experiments, pigs apparently do have a requirement for more carnitine than they are capable of synthesizing, because the results consistently show L-carnitine improving F/G by 10 to 15% in phase 2. However, the exact requirement cannot yet be determined based on the data from these two experiments. Further investigation into other possible roles of carnitine in metabolism will be needed before a carnitine requirement for nursery pigs can be offered.

The data from these experiments show that addition of L-carnitine to starter diets offers the potential to substantially improve feed efficiency.

Table 1. Composition of Diets (Experiment 1)

	Phase 1[a]		Phase 2[b]	
Ingredient	Control	Fat added	Control	Fat added
Corn	41.65	31.50	45.15	40.05
Soybean meal (44% CP)	15.00	15.00	31.00	31.00
Dried skim milk	20.00	20.00	—	—
Dried whey	20.00	20.00	20.00	20.00
Soybean oil	—	10.00	—	5.00
L-lysine HCL	.10	.25	.10	.15
D-L methionine	.10	.10	—	—
Monocalcium phosphate	.90	.90	1.51	1.51
Limestone	.60	.60	.82	.82
Salt	.10	.10	.25	.25
Copper sulfate	.10	.10	.10	.10
Selenium premix[c]	.05	.05	.05	.05
Trace mineral premix[d]	.15	.15	.15	.15
Vitamin premix[e]	.25	.25	.25	.25
Antibiotic[f]	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00

[a]All diets formulated to contain at least 1.3% lysine, .9% Ca, .8% P, and 250 Kcal ME/g lysine.
[b]All diets formulated to contain at least 1.25% lysine, .9% Ca, and .8% P in a constant calorie/lysine ratio.
[c]Each lb contains 272.4 mg Se.
[d]Contains 10% Mn, 10% Fe, 10% Zn, 4% Ca, 1% Cu, .4% K, .3% I, .2% Na, and .1% Co.
[e]Each lb contains: vitamin A, 1,000,000 IU; vitamin D_3, 100,000 IU; vitamin E, 4,000 IU; menadione, 1.32 mg; riboflavin, 2 mg; niacin, 12 mg; d-pantothenic acid, 8 mg; vitamin B_{12}, 8 mg.
[f]Carbadox added at 20 lb/ton.

Table 2. Composition of Diets (Experiment 2)

Ingredient, %	Phase 1[a]	Phase 2[b]
Corn	33.16	47.00
Soybean meal, (44% CP)	18.20	33.10
Dried skim milk	20.00	—
Dried whey	20.00	10.00
Soybean oil	5.00	5.00
L-lysine HCL	.22	.10
D-L methionine	.10	—
Monocalcium phosphate	1.23	1.85
Limestone	.44	.80
Salt	.10	.30
Vitamins/minerals[c]	.55	.55
Antibiotic[d]	1.00	1.00
Total	100.00	100.00

[a]All diets formulated to contain 1.45% lysine, .9% Ca, and .8% P.
[b]All diets formulated to contain 1.25% lysine, .9% Ca, and .8% P.
[c]Same as experiment 1 diet; See Table 1.
[d]Supplied the following per lb of diet: 10 mg furazolidine, 50 mg oxytetracycline, and 45 mg arsanilic acid.

Table 3. Effect of L-Carnitine on Pig Performance (Experiment 1)

	Control			Soybean oil[b]			
	Carnitine, ppm[c]						
Item	0	500	1000	0	500	1000	CV
ADG, lb							
0-2 wk	.65	.70	.61	.69	.68	.70	13.2
3-5 wk[d]	.83	.98	.96	1.02	.98	1.11	15.7
0-5 wk[d]	.76	.87	.83	.90	.87	.94	12.1
Feed Intake, lb/d							
0-2 wk	.65	.70	.66	.71	.69	.70	13.8
3-5 wk	1.69	1.83	1.77	1.88	1.85	1.84	10.5
0-5 wk	1.27	1.38	1.33	1.41	1.38	1.38	9.8
F/G							
0-2 wk	1.03	1.02	1.13	1.08	1.07	1.02	8.6
3-5 wk[df]	2.22	2.00	2.00	2.04	2.00	1.71	14.4
0-5 wk	1.74	1.65	1.67	1.67	1.66	1.48	10.7

[a]A total of 120 weanling pigs, 4 pigs/pen, 5 pens/trt; avg initial wt 12.3 lb, avg final wt 42.5 lb.
[b]Soybean oil levels were reduced by 50% in phase 2.
[c]L-carnitine levels were reduced by 50% in phase 2.
[d]Soybean oil effect (P<.05).
[e]L-carnitine effect linear (P<.05).

Table 4. Main Effects of Feeding L-Carnitine in Phase 1 (Experiment 2)[a]

	Carnitine (ppm)	
Item	0	1000
0-14 d		
ADG, lb[b]	.62	.69
FI, lb/d[c]	.68	.75
F/G	1.23	1.16
15-35 d		
ADG, lb	1.03	1.02
FI, lb/d	1.81	1.90
F/G	1.84	1.96
0-35 d		
ADG, lb	.87	.89
FI, lb/d	1.36	1.44
F/G	1.61	1.66

[a]A total of 180 weanling pigs, 6 pigs/pen, 15 pens/trt; avg initial wt 13.2 lb, avg final wt 43.9 lb.
[b]Carnitine effect (P<.08).
[c]Carnitine effect (P<.02).

Table 5. Effect of L-Carnitine on Pig Performance (Experiment 2)[a]

	Carnitine (ppm)[b]						
Item	0/0	0/250	0/500	1000/0	1000/250	1000/500	CV
ADG, lb							
0-2 wk	.62	.63	.62	.70	.73	.63	13.1
3-5 wk	1.07	.95	1.07	1.06	1.00	1.00	13.7
0-5 wk	.89	.83	.88	.92	.90	.85	11.4
Feed intake, lb/d							
0-2 wk	.67	.72	.66	.78	.77	.69	9.9
3-5 wk[c]	1.98	1.67	1.78	1.95	2.01	1.73	11.6
0-5 wk[d]	1.45	1.29	1.33	1.49	1.52	1.32	9.7
F/G							
0-2 wk	1.24	1.30	1.13	1.17	1.13	1.19	12.2
3-5 wk[de]	1.96	1.88	1.70	1.92	2.19	1.78	9.7
0-5 wk[f]	1.68	1.62	1.54	1.66	1.72	1.59	6.9

[a]A total of 180 weanling pigs, 6 pigs/pen, 5 pens/trt; avg initial wt 13.2 lb, avg final wt 43.9 lb.
[b]Carnitine levels as fed phase 1/phase 2.
[c]Carnitine effect linear (P<.05).
[d]Carnitine effect linear (P<.03).
[e]Carnitine effect quadratic (P<.02).
[f]Carnitine effect: Linear (P<.06).